PATENT COOPERATION TREATY

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INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

(Chapter II of the Patent Cooperation Treaty)

(PCT Article 36 and Rule 70)

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27 JAN. 2006

Applicant's or agent's file reference 34304PC01	**FOR FURTHER ACTION**	See Form PCT/IPEA/416
International application No. PCT/DK2004/000540	International filing date *(day/month/year)* 13.08.2004	Priority date *(day/month/year)* 15.08.2003
International Patent Classification (IPC) or national classification and IPC G06K9/80		
Applicant SCAPE A/S ET AL.		

1. This report is the international preliminary examination report, established by this International Preliminary Examining Authority under Article 35 and transmitted to the applicant according to Article 36.
2. This REPORT consists of a total of 6 sheets, including this cover sheet.
3. This report is also accompanied by ANNEXES, comprising:
   a. ☒ *sent to the applicant and to the International Bureau)* a total of 6 sheets, as follows:
      ☒ sheets of the description, claims and/or drawings which have been amended and are the basis of this report and/or sheets containing rectifications authorized by this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions).
      ☐ sheets which supersede earlier sheets, but which this Authority considers contain an amendment that goes beyond the disclosure in the international application as filed, as indicated in item 4 of Box No. I and the Supplemental Box.
   b. ☐ *(sent to the International Bureau only)* a total of (indicate type and number of electronic carrier(s)) , containing a sequence listing and/or tables related thereto, in computer readable form only, as indicated in the Supplemental Box Relating to Sequence Listing (see Section 802 of the Administrative Instructions).

4. This report contains indications relating to the following items:
   - ☒ Box No. I Basis of the opinion
   - ☐ Box No. II Priority
   - ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - ☐ Box No. IV Lack of unity of invention
   - ☒ Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - ☐ Box No. VI Certain documents cited
   - ☐ Box No. VII Certain defects in the international application
   - ☐ Box No. VIII Certain observations on the international application

Date of submission of the demand	Date of completion of this report
13.06.2005	27.01.2006
Name and mailing address of the international preliminary examining authority: European Patent Office - P.B. 5818 Patentlaan 2 NL-2280 HV Rijswijk - Pays Bas Tel. +31 70 340 - 2040 Tx: 31 651 epo nl Fax: +31 70 340 - 3016	Authorized Officer Sonius, M Telephone No. +31 70 340-3262

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY

International application No.
PCT/DK2004/000540

Box No. I Basis of the report

1. With regard to the **language**, this report is based on the international application in the language in which it was filed, unless otherwise indicated under this item.

   ☐ This report is based on translations from the original language into the following language , which is the language of a translation furnished for the purposes of:
   - ☐ international search (under Rules 12.3 and 23.1(b))
   - ☐ publication of the international application (under Rule 12.4)
   - ☐ international preliminary examination (under Rules 55.2 and/or 55.3)

2. With regard to the **elements*** of the international application, this report is based on *(replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report)*:

Description, Pages	
1-28	as originally filed
Claims, Numbers	
1-36	filed with telefax on 13.06.2005
Drawings, Sheets	
1/16-16/16	as originally filed

   ☐ a sequence listing and/or any related table(s) - see Supplemental Box Relating to Sequence Listing

3. ☐ The amendments have resulted in the cancellation of:
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

4. ☐ This report has been established as if (some of) the amendments annexed to this report and listed below had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).
   - ☐ the description, pages
   - ☐ the claims, Nos.
   - ☐ the drawings, sheets/figs
   - ☐ the sequence listing *(specify)*:
   - ☐ any table(s) related to sequence listing *(specify)*:

* *If item 4 applies, some or all of these sheets may be marked "superseded."*

Box No. V Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-36
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-36
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-36
	No:	Claims	

2. Citations and explanations (Rule 70.7):

see separate sheet

1. Reference is made to the following documents:

D1: RUMMEL P: "A MODEL-BASED VISUAL SENSOR SYSTEM FOR COMPLEX INDUSTRIAL SCENES" SIEMENS FORSCHUNGS- UND ENTWICKLUNGSBERICHTE, SPRINGER VERLAG. BERLIN, DE, vol. 13, no. 3, 1984, pages 151-154, XP002010726 ISSN: 0370-9736

D2: JUVIN D ET AL: "ANIMA (ANALYSES OF IMAGES) A QUASI REAL TIME SYSTEM" PROCEEDINGS - IEEE COMPUTER SOCIETY CONFERENCE ON PATTERN RECOGNITION AND IMAGE PROCESSING 1982. 1982 IEEE, NEW YORK, NY, USA, 1982, pages 358-361, XP002305219

D3: HORNG J-H: "An adaptive smoothing approach for fitting digital planar curves with line segments and circular arcs" PATTERN RECOGNITION LETTERS, NORTH-HOLLAND PUBL. AMSTERDAM, NL, vol. 24, no. 1-3, January 2003 (2003-01), pages 565-577, XP004391198 ISSN: 0167-8655

D4: MINSKY D E ET AL: "Optimal boundary detection on grey-tone image" PATTERN RECOGNITION, PERGAMON PRESS INC. ELMSFORD, N.Y, US, vol. 30, no. 6, 1 June 1997 (1997-06-01), pages 971-998, XP004064090 ISSN: 0031-3203

D5: US-A-5 351 310 (CALIFANO ANDREA ET AL) 27 September 1994 (1994-09-27)

D6: HECKER Y C ET AL: "ON GEOMETRIC HASHING AND THE GENERALIZED HOUGH TRANSFORM" IEEE TRANSACTIONS ON SYSTEMS, MAN AND CYBERNETICS, IEEE INC. NEW YORK, US, vol. 24, no. 9, 1 September 1994 (1994-09-01), pages 1328-1338, XP000462405 ISSN: 0018-9472

D7: US-A-5 828 769 (BURNS J BRIAN) 27 October 1998 (1998-10-27)

Re Item V

Reasoned statement with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement, Article 33(1),(2) and (3) PCT.

2. The subject-matter of claim 1 is new and involves an inventive step, for the following reasons:

2.1 Amongst the cited documents, D5 is considered to be the closest prior art.
D5 discloses a method and system for recognition of three dimensional objects from a two dimensional image of the object (col. 1, lines 9-14), comprising the steps of identifying features, being sets of primitives, for the image (local shape descriptors,

col. 9, lines 14-23);
extracting numerical descriptors of the features of extrinsic and intrinsic properties of the features (col. 9, line 32- col. 10, line 2).
matching said properties with those stored in a database for known objects (figure 5, 7).

2.2 D5 does not disclose applying a homographic transformation to the features.

2.3 The objective technical problem solved by this feature is to enable matching of images subject to strong perspective.

2.4 Neither this problem, nor the solution is known from any of the cited documents. Hence the subject-matter of claim 1 cannot be deemed to follow in a straightforward manner from the prior art.

3. The subject-matter of claim 20 concerns a method for generating a database as used in the method of claim 1, including the step of extracting intrinsic properties of features after applying a homographic transformation to the features.

3.1 Therefore also the subject-matter of claim 20 is to be considered as involving an inventive step, for the same reasons as formulated in above items 2.2-2.4.

4. Dependent claims 2-19 and 21-36 have a further limiting effect and therefore also comprise new and inventive subject-matter.

Re Item VIII

Certain observations on the international application

5. It is noted that the definition of the particular homographic transformation that is applied appears to be an essential feature of the invention. Hence the present claims are not deemed to meet the requirement of support by the description, Article 6 PCT.

INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY (SEPARATE SHEET)

International application No.

PCT/DK2004/000540

Druckexemplar

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AMENDED CLAIMS, 10 June 2005; response to Written Opinion

1. A method for recognition, such as classification and/or localisation of three dimensional objects, said one or more objects being imaged so as to provide a recognition image being a two dimensional digital image of the object, said method utilises a database in which numerical descriptors are stored for a number of training images, the numerical descriptors are the intrinsic and extrinsic properties of a feature, said method comprising:
- identifying features, being predefined sets of primitives, for the image
- extracting numerical descriptors of the features, said numerical descriptors being of the two kind:
  - extrinsic properties of the feature, such as the location and orientation of the feature in the image, and
  - intrinsic properties of the feature derived after a homographic transformation being applied to the feature
- matching said properties with those stored in the database and in case a match is found assign the object corresponding to the properties matched in the database to be similar to the object of the object to be recognised.

2. A method according to claim 1, for matching a recognition image with training images stored in a database, wherein the matching comprising the following steps:
- for each training image:
- determining the values of roll, tilt and pan of the transformations bringing the features of the recognition image to be identical with the features of the training image;
- identify clusters in the parameter space defined by the values of roll, tilt and pan determined by said transformations

and

- identify clusters having predefined intensity as corresponding to an object type and localisation.

3. A method according to claim 1 or 2, wherein the database comprise for each image one or more records each representing a feature with its intrinsic properties and its extrinsic properties.

4. A method according to claim 3, wherein the matching comprises the steps of:
- resetting the roll, tilt and pan parameter space,
- for each feature in the recognition image, matching properties of the recognition image with the properties stored in the database,

- in case of match: determining roll, tilt, and pan based on the extrinsic properties from the database and from the recognition image,
- updating the parameter space, and
- test for clustering and store coordinates of clusters with sufficiently high density/population with an index of the training image,
- repeating the steps until all features in the recognition image have been matched.

5. A method according to claim 4 wherein the determination of the roll, tilt and pan are only done for features having similar or identical intrinsic properties compared to the intrinsic properties in the database.

6. A method according to claim 4 wherein the matching comprises comparing the intrinsic descriptors of the recognition image with the intrinsic descriptors stored in the database thereby selecting matching features.

7. A method according to claim 1 to 6, wherein the generation of said database comprises determination of contours, preferably level contours, and primitives in a digital image, said determination comprising the steps of:

- generating the gradients of the digital image;
- finding one or more local maxima of the absolute gradients;
- use the one or more local maxima as seeds for generating contours, the generation of the contours for each seed comprising determining an ordered list of points representing positions in the digital image and belonging to a contour;
- for all of said positions determining the curvature, preferably determined as dθ/ds preferably pixel units, of the contours;
- from the determined curvatures determine primitives as characteristic points on or segments of the contours.

8. A method according to claim 7 further comprising the step of eliminating potential seed points identified near already defined contours.

9. A method according to any of the claims 7-8, wherein the generation of the contours comprising assigning the list of points representing positions in the digital image, each point having a value being assigned to be common with the value of the seed.

10. A method according to any of the claims 7-8, wherein the generation of the contours comprising assigning the list of points following in each point the direction of the maximum or minimal gradient detected perpendicular to a contour direction.

11. A method according to claim 7-8, wherein the generation of the contours comprising assigning the list of points with values being above or below the value of the seed and one or more neighbour pixels with value below or above said value of the seed.

12. A method according to claim 7-11, wherein the list of pixels is established by moving through the digital image in a predetermined manner.

13. A method according to claim 8-12, wherein the contours being determined from an interpolation based on the list of pixels.

14. A method according to claim 8-13 wherein the list is an ordered list of pixels.

15. A method according to claim 7-14, wherein the gradients are determined by calculating the difference between numerical values assigned to neighbouring pixels.

16. A method according to claim 7-15, wherein the gradients are stored in an array in which each element corresponds to a specific position in the first image and being a numerical value representing the value of the gradient of the first image's tones in the specific position.

17. A method according to claim 7-16, wherein the curvatures being established as $\kappa = d\theta/ds$ where θ is the tangent direction at a point on a contour and s is the arc length measured from a reference point.

18. A method according to any of the claims 7-17, wherein the primitives comprise of one or more of the following characteristics:

- segments of straight lines,
- segments of relatively large radius circles,
- inflection points,
- points of maximum numerical value of the curvature, said points being preferably assigned to be corners,
- points separating portions of very low and very high numerical value of the curvature, and
- small area entities enclosed by a contour.

19. A method according to any of the claims 7-18, wherein each contour is searched for one or more of the following primitives:

- inflection point, being a region of or a point on the contour having values of the absolute value of the curvature being higher than a predefined level;

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- concave corner, being a region of or a point on the contour having positive peaks of curvature;
- convex corner, being a region of or a point on the contour having negative peaks of curvature;
- straight segment, being segments of the contour having zero curvature;

and/or

- circular segments, being segments of the contour having constant curvature.

20. A method of generating a database useful in connection with localising and/or classifying a three dimensional object, said object being imaged so as to provide a two dimensional digital image of the object,
wherein the determination of primitives in the two dimensional digital image of the object comprises the steps of

- generating the gradients of the digital image;
- finding one or more local maxima of the absolute gradients;
- use the one or more local maxima as seeds for generating contours, the generation of the contours for each seed comprising determining an ordered list of points representing positions in the digital image and belonging to a contour;
- for all of said positions determining the curvature, preferably determined as dθ/ds preferably pixel units, of the contours;
- from the determined curvatures determine primitives as characteristic points on or segments of the contours.

said method further comprising:

- identifying features, being predefined sets of primitives, in a number of digital images of one or more object, the images represent different localisations of the one or more object;
- extracting and storing in the database, numerical descriptors of the features, said numerical descriptors being of the two kind:
- extrinsic properties of the feature, that is the location and orientation of the feature in the image, and
- intrinsic properties of the feature being derived after a homographic transformation being applied to the feature.

21. A method according to claim 20 further comprising the step of eliminating potential seed points identified near already defined contours.

22. A method according to any of the claims 20-21, wherein the generation of the contours comprising assigning the list of points representing positions in the digital image, each point having a value being assigned to be common with the value of the seed.

23. A method according to any of the claims 20-21, wherein the generation of the contours comprising assigning the list of points following in each point the direction of the maximum or minimal gradient detected perpendicular to a contour direction.

24. A method according to claim 20-21, wherein the generation of the contours comprising assigning the list of points with values being above or below the value of the seed and one or more neighbour pixels with value below or above said value of the seed.

25. A method according to claim 20-24, wherein the list of pixels is established by moving through the digital image in a predetermined manner.

26. A method according to claim 21-25, wherein the contours being determined from an interpolation based on the list of pixels.

27. A method according to claim 21-26 wherein the list is an ordered list of pixels.

28. A method according to claim 20-27, wherein the gradients are determined by calculating the difference between numerical values assigned to neighbouring pixels.

29. A method according to claim 20-28, wherein the gradients are stored in an array in which each element corresponds to a specific position in the first image and being a numerical value representing the value of the gradient of the first image's tones in the specific position.

30. A method according to claim 20-29, wherein the curvatures being established as $\kappa=d\theta/ds$ where θ is the tangent direction at a point on a contour and s is the arc length measured from a reference point.

31. A method according to any of the claims 20-30, wherein the primitives comprise of one or more of the following characteristics:

- segments of straight lines,
- segments of relatively large radius circles,
- inflection points,
- points of maximum numerical value of the curvature, said points being preferably assigned to be corners,
- points separating portions of very low and very high numerical value of the curvature, and
- small area entities enclosed by a contour.

32. A method according to any of the claims 20-31, wherein each contour is searched for one or more of the following primitives:

- inflection point, being a region of or a point on the contour having values of the absolute value of the curvature being higher than a predefined level;
- concave corner, being a region of or a point on the contour having positive peaks of curvature;
- convex corner, being a region of or a point on the contour having negative peaks of curvature;
- straight segment, being segments of the contour having zero curvature;

and/or

- circular segments, being segments of the contour having constant curvature.

33. A method according to any of the claims 1-32, wherein the extrinsic properties comprises a reference point and a reference direction.

34. A method according to any of the claims 1-33, wherein the intrinsic properties comprises numerical quantities of features.

35. A method according to any of the claims 1-19 wherein the object being imaged by at least two imaging devices thereby generating at least two recognition images of the object and wherein the method according to any of the claims 1-34 are applied to each recognition image and wherein the match found for each recognition image are compared.

36. A method according to claim 35, where the method comprising the steps of:

- for each imaging device, providing an estimate for the three dimensional reference point of the object,
- for each imaging device, calculating a line from the imaging device pinhole to the estimated reference point,

and when at least two or more lines have been provided,

- discarding the estimates in the case that the said two or more lines do not essentially intersect in three dimensions,

and when the said two or more lines essentially intersect,

- estimating a global position of the reference point based on the pseudo intersection between the lines obtained from each imaging device.